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the role of transportation of energy in the development of the southwest

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THE ROLE OF TRANSPORTATION OF ENERGY IN THE DEVELOPMENT OF THE SOUTHWEST

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LAKE POWELL RESEARCH PROJECT

The Lake Powell Research Project (formally known as Collaborative Research on Assessment of Man's Activities in the Lake Powell Region) is a consortium of university groups funded by the Division of Advanced Environmental Research and Technology in RANN (Research Applied to National Needs) in the National Science Foundation.

Researchers in the consortium bring a wide range of expertise in natural and social sciences to bear on the general problem of the effects and ramifications of water resource management in the Lake Powell region. The region currently is experiencing converging demands for water and energy resource development, preservation of nationally unique scenic features, expansion of recreation facilities, and economic growth and modernization in previously isolated rural areas.

The Project comprises interdisciplinary studies centered on the following topics: (1) level and distribution of income and wealth generated by resources development; (2) institutional framework for environmental assessment and planning; (3) institutional decision-making and resource allocation; (4) implications for federal Indian policies of accelerated economic development of the Navajo Indian Reservation; (5) impact of development on demographic structure; (6) consumptive water use in the Upper Colorado River Basin; (7) prediction of future significant changes in the Lake Powell ecosystem; (8) recreational carrying capacity and utilization of the Glen Canyon National Recreation Area; (9) impact of energy development around Lake Powell; and (10) consequences of variability in the lake level of Lake Powell.

One of the major missions of RANN projects is to communicate research results directly to user groups of the region, which include government agencies, Native American Tribes, legislative bodies, and interested civic groups. The Lake Powell Research Project Bulletins are intended to make timely research results readily accessible to user groups. The Bulletins supplement technical articles published by Project members in scholarly journals.

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ABSTRACT

Today's major railroads and highways in the Southwest follow what were originally wagon train trails to California. For example, the Old Spanish Trail, later termed the Mormon Corridor, became the route for Interstate Highway 15 and portions of the Union Pacific Railroad. Within relatively few years in the nineteenth century most of the Southwest's major railroad network was established. The railroad stimulated the growth of towns such as Las Vegas, Flagstaff, Odgen, and Grand Junction, which became nuclei for regional development.

When railroad development tapered off in the early twentieth century, vast areas of the Southwest remained unserved by transportation corridors. A prime example of an isolated region is the Kaiparowits Plateau of southern Utah, whose large coal reserves remain unexploited largely for lack of means to transport them to energy use centers. The region lacks many professional services and must pay higher prices for many goods and services. At the same time, isolation has conferred the benefits of an undisturbed environment, lack of congestion, close person-to-person relationships, and a slower way of life.

It is well established that creation of transportation links with the "outside world" may have a profound effect upon the economy and the way of life of heretofore isolated communities. The impact will depend upon whether the transportation corridor is single-purpose, such as would be a coal slurry pipeline or a dedicated railroad, or general-purpose, such as a common-carrier railroad. Local, state, and regional planning and permitting agencies may be expected

to take these indirect impacts into account when considering energy transportation proposals.

It is recognized that the total cost of an energy transportation project consists of "hard costs" which are directly measurable in traditional ways, and "soft costs" which reflect social impacts, political conflict, environmental damage, and other less readily quantifiable impacts. Today soft costs and benefits are playing an increasingly important role in decision making for western energy projects.

General models for estimating the hard costs of unit train and coal slurry pipeline transportation of coal were developed and run. It was found that at low annual throughputs (about 3 million tons per year) rail transportation costs per ton-mile would always be cheaper, while for throughputs above 50 million tons per year, pipelines would be cheaper. In intermediate ranges the cost differential depends upon the percentage of new rail construction and the number of pipelines. Ton-mile costs may be misleading, however, since rail and pipeline distances between the same origin and destination may be quite different. In addition, soft costs such as the political difficulty of obtaining water for slurry pipelines may in effect outweigh the hard costs.

INTRODUCTION

It is well known that improvement in transportation facilities can produce social change. Once an important transportation facility has been introduced into a region, labor specialization, integration of the local economy into regional and national trade systems, and infusion of capital in the local economy generally result. Local customs and beliefs are challenged by cosmopolitan customs and beliefs. The location of many western cities was determined by the choice of railroad routes, primarily by the railroad companies themselves.

Conversely, a region which is not traversed by major transportation routes tends to remain insular, and to survive it must become more self-sufficient than neighboring regions which benefit from important transportation corridors. The communities in such regions have remained isolated and undeveloped, unless later connected to urban areas by freeways. Such areas often lack vital services such as those provided by physicians, dentists, hospitals, and attorneys. Costs for many commodities are significantly higher in remote areas than in areas better served by transport. Isolation may confer benefits also: an undisturbed environment, lack of congestion, person-to-person relationships, and a slower paced way of life.

Obviously, energy resources are most easily exploited in those areas in which transportation corridors already exist. A good example is the case of Utah; its largest and richest coal reserve, the Kaiparowits Plateau, has not been mined, at least partly because it is not served by any transportation corridors. Other Utah coalfields, such as those in Carbon and Emery Counties, are served by rail transportation and may be rapidly expanded to respond to increased demand.

The State of Utah contains a large number of coalfields, and its total coal reserve, according to the Bureau of Mines,[1] is 4 billion tons. The Kaiparowits field, according to the Bureau, contains 2.9 billion tons of coal.[2] Thus, the active coal mines of Utah are within the smaller reserves of the state, and the largest reserve is unexploited and has been bypassed by transportation corridors to coal markets. No railroads or superhighways traverse the Kaiparowits Plateau. Very few paved roads exist there, and many of the unpaved roads of the area encircle, but do not cross, the Kaiparowits region. Most of the paved roads have been constructed to serve the many national parks, national monuments, and other recreational areas which surround the Kaiparowits Plateau.

Figure 1 shows the existing major coalfields and railroad route facilities in the Southwest.

One of the important consequences of the construction of a major transportation route into a remote area is the socioeconomic change which may result from the availability of new transport facilities. In this regard, the construction of a new slurry pipeline or a single-purpose railroad can have quite different impacts upon the social fabric of a region than would the construction of a new general-purpose rail line. Any new facility in which general goods and services (in addition to mineral or energy raw materials) can be transported will have far-reaching consequences to the local economy. A pipeline, or a single-purpose railroad, will provide a smaller stimulus for long-term social change than will a general-purpose railroad.

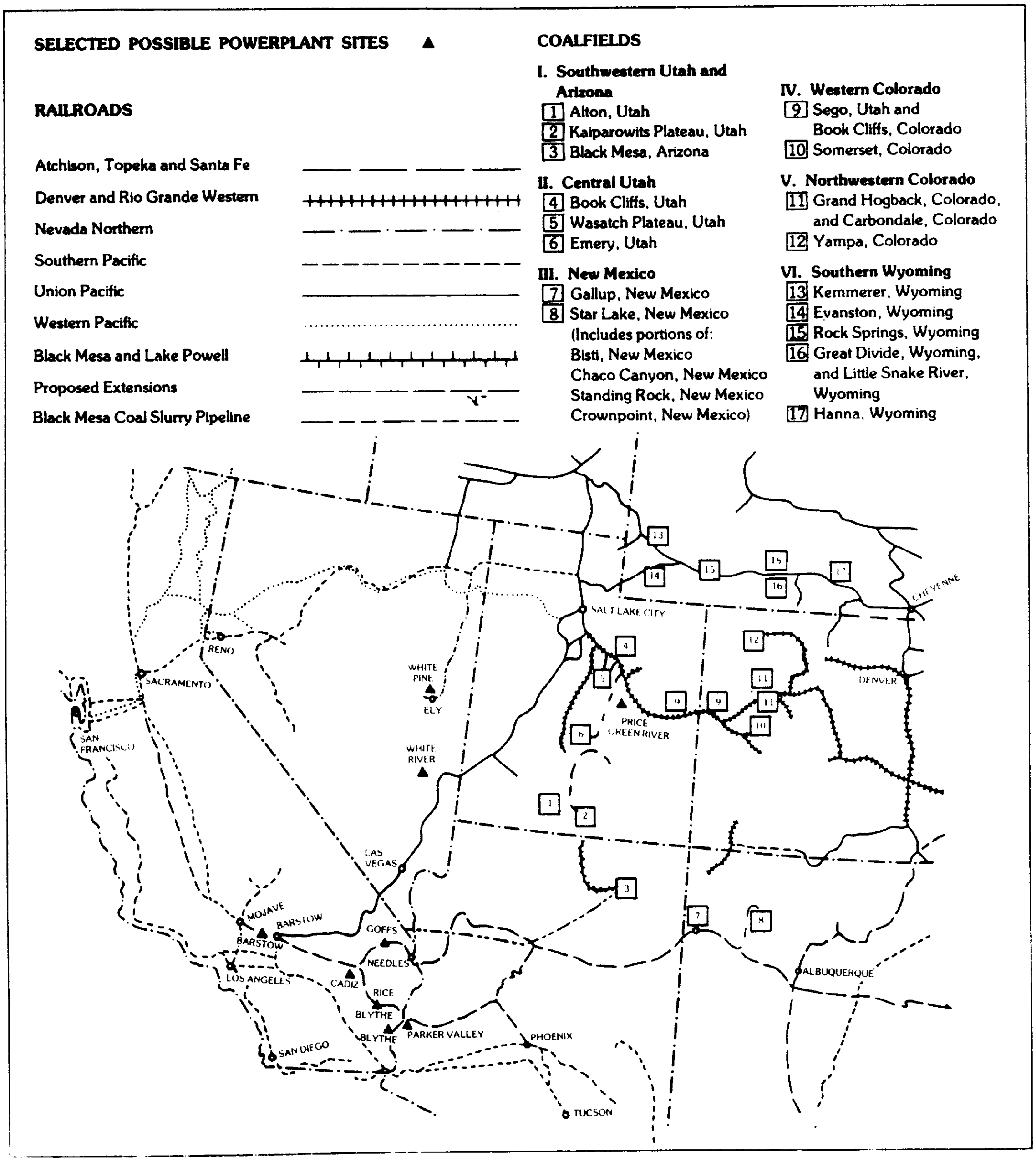

Figure 1: Southwestern Railroads and Coalfields

We are not suggesting that it is the responsibility of industry to choose one kind of transportation over the other merely on the basis of the ultimate impact upon the social fabric of the producing region. We are, however, suggesting that the regional economic and social structure has a big stake in the type of transportation system that is chosen. For this reason, state and regional planners may have a keen interest in the mode of transportation being planned to serve remote areas under their jurisdiction. Since the cooperation of these officials is required for the construction and operation of a new transportation corridor, some consideration of social impact should go into industrial planning as well.

At the present time, decisions on the transportation mode for energy projects are usually made under the constraint that returns on project investment must finance the transportation system, without outside subsidy. For example, the planned transportation of energy in the proposed Kaiparowits project was to have been via electrical transmission lines. On the other hand, coal is transported by slurry pipelines to the Mohave Generating Station and by single-purpose rail line to the Navajo Generating Station. We have no doubt that these transportation solutions are the correct ones within the constraints imposed by the financing of the particular project: namely that the transportation mode chosen is paid for entirely by the expected revenues of the particular project.

It is to be expected that state planners in the western states, in fulfilling their responsibilities, will consider criteria additional to the financial constraints of the industrial approach before they approve a new transportation system. They may consider the long- and short-term economic interests of the producing region (state and local), and that later projects benefit greatly from the existence of the multipurpose transportation corridor established by the first project. A case can be made that an undeveloped, isolated region can benefit economically much more from the establishment of a multipurpose transportation system than it can from a restricted transportation system. On the other hand, long-term social and environmental costs accrue to a region whenever a new major transportation corridor is introduced into a region.

These long-term costs (and benefits) can be termed "soft" costs (and benefits), in contrast to the "hard" costs (and benefits) arising from straightforward analyses of capital and operating costs. Other major soft costs include legal expenses and loss of interest on capital, due to extended delays arising from environmental challenges in hearings and in lawsuits. Today soft costs (and benefits) are beginning to rival the hard costs (and benefits) in some western power projects.

The decision to undertake the serious planning of a new transportation corridor will probably stem from the necessity of transporting energy or raw materials from a mine to a particular proposed site for a power project. Thus, the stimulus for a new transportation corridor is likely to be a proposed power project.

In the next section we briefly review the history of the role of transportation corridors in the development of the Southwest. Later we consider some of the hard costs of establishing a transportation system in the southwestern United States for transporting coal-based energy to a plant in a Southwest load center.

EARLY TRANSPORTATION CORRIDORS IN THE SOUTHWEST

Today's major railroads in the Southwest follow routes which were wagon train trails to California. These trails were determined by water supplies and topography. Watering stops on these trails are now major towns. Grew has summarized the relationship between present transportation corridors and original wagon train trails.[3]

A good example is the Old Spanish Trail between San Bernardino, California, and southern Utah over Cajon Pass. This became the Mormon Corridor (Figure 2), established during the time of expansion of Mormon communities when it was proposed to establish a large state connecting what is now Utah to the Pacific Ocean. In the attempt to establish this "State of Deseret," San Bernardino was colonized and became a thriving community by 1855, when Los Angeles was still a "wild cowtown."[3,4] The trade route from San Bernardino to Los Angeles later became Highway 66, and the Mormons established Las Vegas, Nevada, as an oasis halfway between Cedar City, Utah, and San Bernardino.[3,5]

The Mormon Corridor was important for wagon trains during the Gold Rush. Streams of people passed through Salt Lake City on their way to California and developed two important wagon train trails, one following the Corridor (Figure 2) which today is the route for Interstate 15

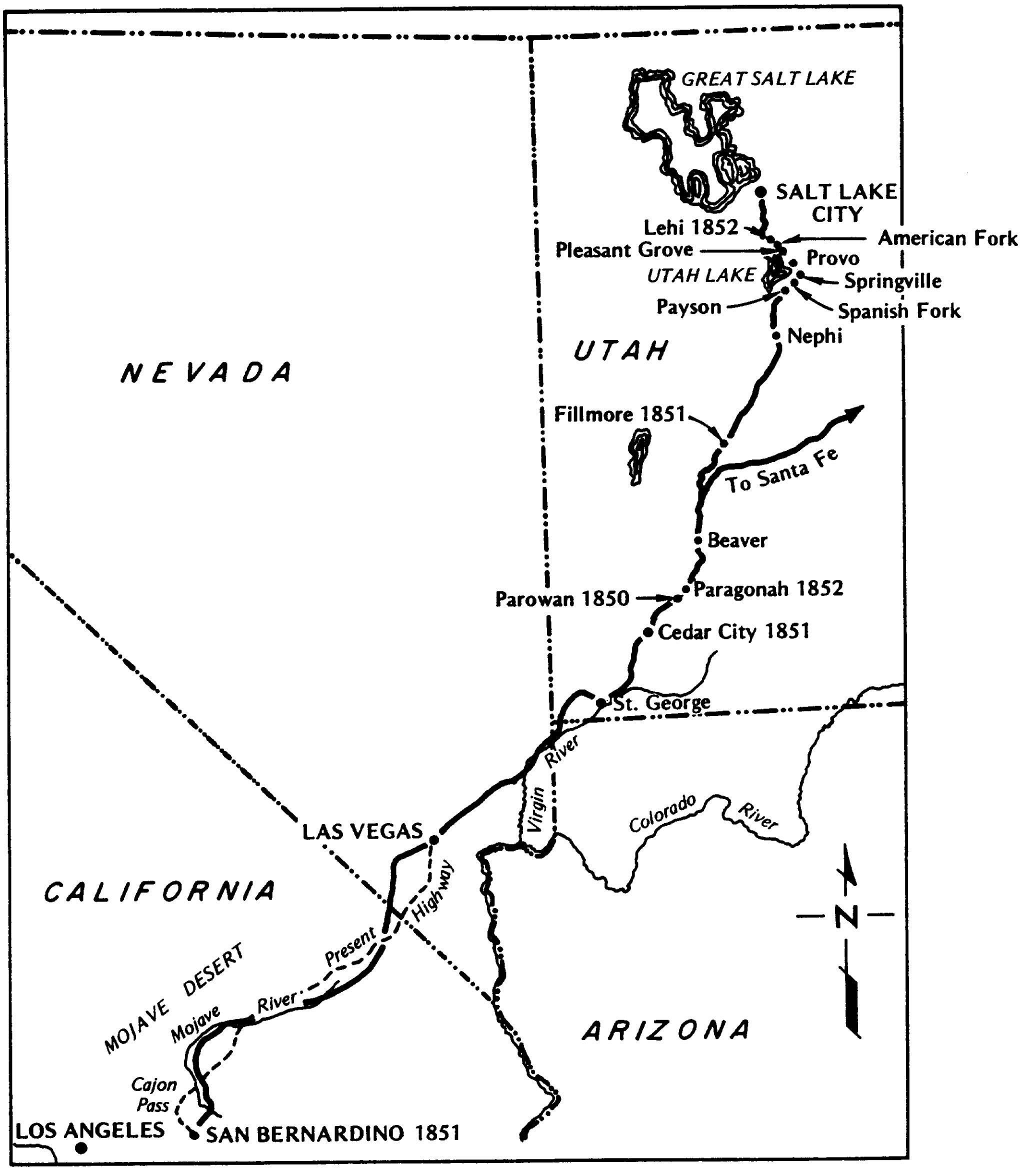

Figure 2: The Mormon Corridor

Sources: Reference 3 (Figures 2 and 3) and Reference 8 (Figure 2) and the Union Pacific Railroad between Salt Lake City and Los Angeles.

The Union Pacific Railroad line was built between San Francisco and Chicago along the general trend of the northern wagon train trail shown in Figure 3. This railroad was designed mainly for the transportation of mineral wealth to the East, and it was built deliberately to bypass Salt Lake City, in spite of protests from the Mormon community.[6] The Union Pacific line passed through Ogden, Utah, and this railroad town became the hub for the passage of coal transported by the Union Pacific from coal mines near Rock Springs, Wyoming, to Salt Lake City. Such a lucrative monopoly on energy transportation led to cries of "the rapacity of the railroad monopolies" by the Salt Lake City community.[6] Partly to compete with the Union Pacific for transportation of coal to Salt Lake City and Denver, the Rio Grande Railroad was built in 1883, directly connecting these two cities, and passing through the region of the rich underground coal reserves of Carbon and Emery Counties, Utah. This was a clear case of a railroad being built in the West mainly for the purpose of transporting energy resources directly from coal mines to the load center.

San Francisco was the main hub on the Pacific coast, and connections to the East by a southern route were made by the Southern Pacific Railroad line. The Southern Pacific line from San Francisco reached Los Angeles in 1876, extended east to Yuma, Arizona, by 1877, and connected to the Atchison, Topeka & Santa Fe line at Demming, New Mexico, by 1881. In the meantime, the Atlantic and Pacific Railroad (now part of the Santa Fe line) connecting the Santa Fe line at Albuquerque to Needles, California, was

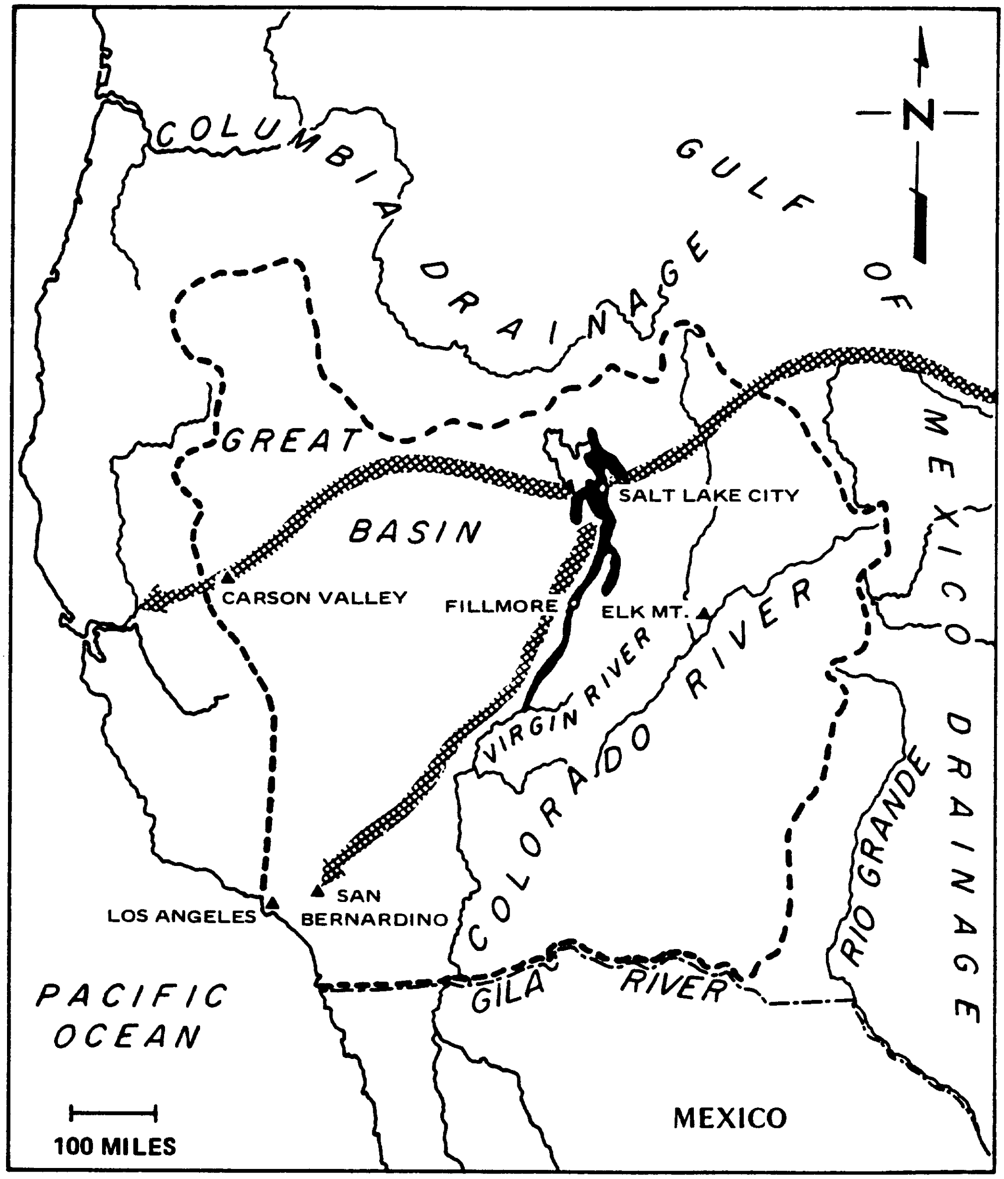

Figure 3: Routes to California through Deseret. Mormon settlement areas (black) and Fillmore (capital of Utah from 1851 to 1856) are shown. Boundary of Deseret is dashed line.

Sources: Reference 3 (Figures 2 through 5) and Reference 9 (Figure 2) completed.[7] In 1885, San Bernardino was connected by a rail line over Cajon Pass to Barstow (along the Mormon Corridor) where it joined the transcontinental Santa Fe line. In 1887, the Santa Fe line was extended from San Bernardino to Los Angeles, which had previously only been on the Southern Pacific system.[8]

Thus, within a very few years the major general-purpose railroad lines which are now the major-use corridors of today were established. The routes that were laid out within those few years had a significant effect on the towns along the way. A good case in point is Las Vegas.

Meining reported that the completion of the rail line between Salt Lake and Los Angeles re-established Las Vegas "as an important way station to California," and that it became a "somewhat altered refreshment stop along the new-style Mormon Corridor."[3,9] In the era of coal-fired engines, the rail lines had to be built on routes accessible to cooling water. Therefore the rail lines tended to follow the early wagon trails where the water supply problem was the same. With the advent of diesel engines, the water supply problem disappeared, but by that time the location of railroad towns, like Las Vegas, Flagstaff, Needles, Barstow, Ogden, Gallup, Grand Junction, Elko, and Helper, was fixed. The railroad had fulfilled its role in the nucleation of these communities, the social fabric of the surrounding area was established, and regional growth extended from the grid of these railroad towns.

The pattern of the southwestern railroads was fixed by 1900, and little has been done since then to change the major general-purpose transportation routes. Railroad development in the Southwest ended before the route density approached that of the East. There were then, and still are, vast regions lacking major transportation routes (Figures 1 and 4).

In the early 1900s, an engineer named Robert Brewster Stanton recognized one major gap in the railroad network of the Southwest: the region surrounding the proposed Kaiparowits power development site, indicated by K on Figure 4. He argued that a new railroad was needed because the area between the Santa Fe line on the south and the Rio Grande line on the north was the "largest portion of the United States remaining unsupplied by railroad facilities."[10] Stanton had his eye on the coalfields of southern Utah and a route along the Virgin River and the Colorado River to a point about 50 miles (80 kilometers) north of Yuma, Arizona, then west to California.

Stanton failed to build his proposed railroad, but the significance of his observation is still valid today. The largest and richest coalfield within reach of Los Angeles, the Kaiparowits field, is still unexploited largely because of the absence of adequate transportation facilities.

In 1976 the proposed Kaiparowits project of southern Utah was withdrawn by its sponsors, and environmental groups were quick to assume that credit for this withdrawal was due to their pressure. But had the transportation facilities existed, there would have been exploitation of Kaiparowits coal long before air quality standards were a factor in determining the construction of a powerplant.

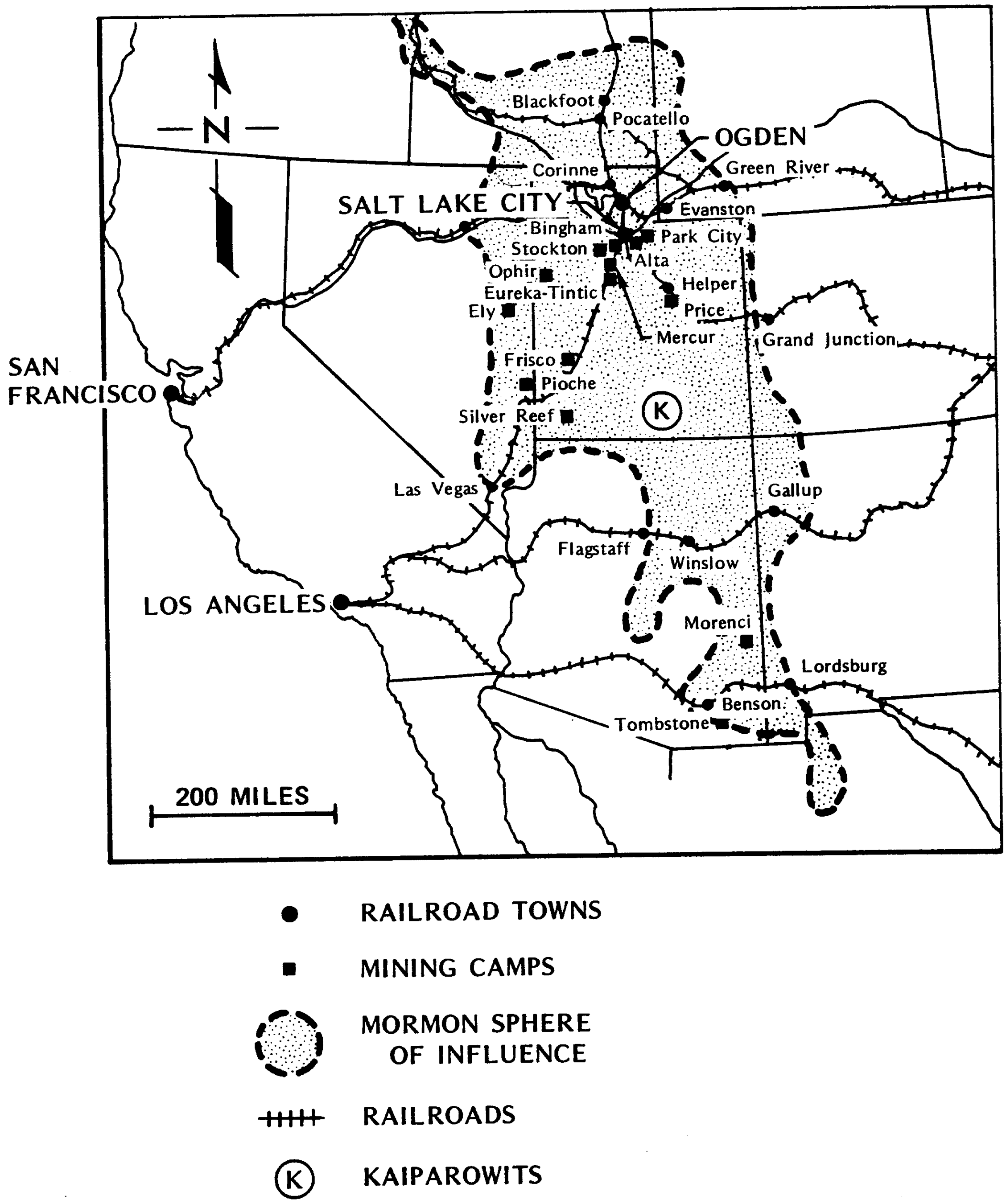

Figure 4: Map of Mining Camps, the Railroads, and the Mormon Sphere of Influence

Sources: Reference 3 (Figures 2 through 8) and Reference 9 (Figure 5)

Stanton observed:[10]

> "Of the two and a half million tons used annually in California from San Francisco south about one and a quarter million tons are imported annually from foreign countries--British Columbia, Australia, Japan, England, Scotland, and Wales. And the greater part of the remaining one half comes from Puget Sound.
>
> "As far as is known, there is only one place in this whole section [southern Utah, Nevada, Arizona, California] where there exists an adequate deposit of coal ...only one body of coal [the one in southern Utah] exists in quantity, quality, and position capable of supplying the demands of this territory for now and the future."

The certainty of the coal resource in southern Utah is a fixed quantity, compared to the transient nature of national energy planning, pricing control, regulations of various bureaus, commissions, and boards dealing with electrical energy, availability of foreign energy sources, and climatic fluctuations.

Sooner or later the right combination of events will occur so that coal in Kaiparowits may be mined and the energy transported. Until that time, Kane and Garfield Counties, which surround this coalfield, are very apt to remain isolated. These two counties, though spanning a vast area of canyon country, together have a population of only about 7,000. The social fabric of the Mormon communities, such as Escalante, near the coalfields of southern Utah is very much unlike those present southwestern communities which started out as railroad towns.

The kind of transportation facility which will be built to transport coal or its derived energy from southern Utah to the load centers of California will have a tremendous effect on the future structure of the communities of southern Utah, if the past record of railroads can be used as a guide.

Recent experience with the development of large-scale mining in rural areas of the western states has shown that local communities have been transformed, and the character of the towns has been greatly changed, often to their detriment.[11]

ASSUMPTIONS ABOUT THE CONSTRUCTION OF A COST MODEL

Given this picture of the role of transportation in the development of the Southwest, let us now turn our attention to the economic constraints, or "hard" costs, on the extension of the transportation network and, hence, on future energy development in the region. Although, as discussed in the previous section, many energy resource areas are served by roads and railroads, the opening of important new coal regions, such as the Kaiparowits Plateau, to development will require substantial new transportation infrastructure. Given the rough topography, engineering, construction, and operating problems will be more difficult than in the northern Great Plains or other coal mining areas, and transportation costs may be significantly higher.

In a previous study[12] we constructed a computer model to estimate the costs of transporting coal by unit train or slurry pipeline from coalfields in Utah, Arizona, New Mexico, Colorado, and Wyoming to potential powerplant sites in Southern California. In the present analysis, we have taken the model from that study and have extended it to compare the costs of rail and slurry pipeline transportation in general. The general assumptions which guide the present analysis follow:

- Transportation costs reflect rail or pipeline construction, rolling stock, loading and unloading facilities, pumping and dewatering facilities (for pipelines), and operations--no matter who actually pays them

- Capital costs are converted to annualized capital costs through multiplication by a single "fixed charge rate" (FCR) which is defined as the sum of interest or cost of money, depreciation, interim replacements, property insurance, and federal, state, and local taxes[13]

- An FCR of 0.15, which is consistent with public and private utility practice, although at the low end of reported ranges, was used;[13,14] financing of all capital items would be for 30 years

- Unit trains would be used for all rail transportation, over single track

- Costs are expressed in January 1977 dollars

To compensate for uncertainties in the data, we built adjustable variables for FCR, coal heating value, and new rail construction cost into the model. Although we have used reasonable values for these parameters, other values may be substituted as new data become available.

Most of the cost data used in this analysis were reported in the 5 years up to and including 1976. To "inflate" capital equipment and operating costs to January 1977 dollars, we used seasonally adjusted Gross National Product implicit price deflators, while rail and pipeline construction costs were inflated with the construction cost index for building.[15]

TRANSPORTATION COST MODEL EQUATIONS

Because much of the information on railroad and slurry pipeline construction is proprietary, it is difficult for those outside the industry to estimate coal transportation costs accurately. Differing assumptions have led to widely varying results, at least for rail transportation costs[16,17] and recent years have seen a good deal of controversy over comparisons of rail and slurry costs.[18,19,20] In the work in which the model used here is described,[12] we have made every effort to make all our assumptions explicit. For the purpose of this Bulletin, which is extended to the general case for the western states, but which does not specifically include the detailed factors of the previous study,[12] we propose some general formulae and observations.

Rail Transportation

Most coal transportation cost estimates have been based upon surveys of rail tariffs, rather than upon actual costs. Tariff-based estimates, however, may be inapplicable to new coal developments in those areas of the Colorado River Basin which are partially or totally lacking in rail infrastructure. We therefore chose to estimate the total cost of developing new rail infrastructure, purchasing and maintaining rolling stock and coal-handling facilities, and operating a unit train on a year-round basis.

Figure 5 outlines the procedure used for estimating hopper car and locomotive requirements and costs; it follows, with some modifications, a methodology used by the Interagency Task Force in preparing the Federal Energy Administration's Project Independence Blueprint[21] and by others.[22,23] Operating costs include those for coal handling and unit train operation. We estimated the latter by isolating operating costs from an empirical tariff formula developed by Bechtel Corporation.[24] Capital and operating costs for coal-handling facilities were estimated in a Los Alamos Scientific Laboratory study of coal transportation.[25]

Equation (1) shows the annual rail transportation cost (RRD) as a function of coal throughput, the number of tons per year (TPY), and the total haulage distance in miles (RAILD). NEWRL (in miles) is the new rail distance, and SPCON (dollars) is the sum of bridge, tunnel, and special earthwork costs.

$$\begin{aligned} \text{RRD (\$/year)} = {} & [5.28 \times 10^{-5}\ \text{TPY}\ (124\ \text{RAILD} \\ & + 1.24 \times 10^{5}) + 1.0 \times 10^{6}\ \text{NEWRL} \\ & + \text{SPCON} + 1.15 \times 10^{7}]\ \text{FCR} \\ & + 6.94 \times 10^{-2}\ \text{TPY} \times \text{RAILD}^{0.609} \\ & + 4.0 \times 10^{5} \end{aligned} \tag{1}$$

Coal Slurry Pipeline

Our analysis was based primarily on data provided by Bechtel Corporation, the designer of the Black Mesa pipeline, to the Transportation Task Force of the Project

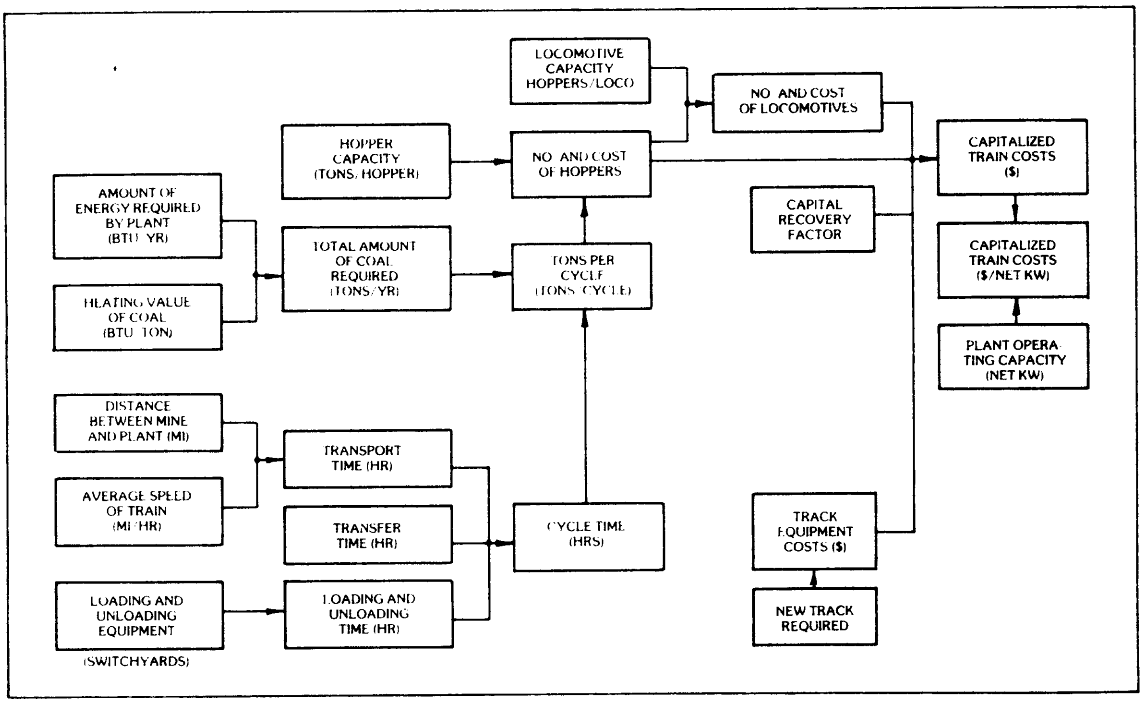

Figure 5: Unit Train Cost Estimation Procedure

Independence Blueprint study.[21] After adjustment to reflect 1977 costs, and rearrangement, we changed the Bechtel formula for annual pipeline transportation cost (CPD) to obtain the following:

$$\begin{aligned} \text{CPD (\$/year)} = {} & [\text{PDIST} \; (76.0 \; \text{TPY}^{0.5} + 118000) \\ & + 2.65 \times 10^{7}] \; \text{FCR} + 2.23 \; \text{TPY} \; [1 \\ & + (\text{PDIST})(\text{TPY}^{-0.5})] \end{aligned} \tag{2}$$

where PDIST (in miles) is the transportation distance.

APPLICATION OF THE COST MODELS

We used equations (1) and (2) to compute annual rail and slurry pipeline transportation costs, respectively, for a range of throughputs and haulage distances likely to characterize Colorado River Basin energy development in the near future. It is anticipated that both new rail construction and upgrading of existing rail lines will be necessary to permit use of unit trains; accordingly, for each coal haulage volume examined, we calculated the costs for 0-, 10-, 50-, and 100-percent new construction and for the same percentages of upgrading.

Estimates for the unit cost of new rail construction for proposed new railroads in Utah and New Mexico[26,27,28] range from $714,000 to $2,368,000 per mile. Other estimates include $300,000 per mile for single track[29] and $1,584,000 per mile for double track.[30] All these estimates are subject to different assumptions about land costs, signalling, ancillary equipment, labor, and financing, so no single one is "correct." To aid in computation and yet remain well within the reported range, we assume that new rail will cost $1,000,000 per mile. The cost of upgrading and/or replacing existing rail was set at $140,000 per mile.[31] For this exercise, no tunnels or bridges were assumed necessary for expansion of the rail network, although they will certainly add significantly to the cost of any connections between southern Utah coalfields and existing main lines. Coal slurry pipeline costs estimated here are for all-new systems.

Figures 6 through 11 show the results of applying the rail and slurry cost models. To facilitate intermodal comparison, costs are expressed in mills per ton-mile. The reader is cautioned that this measure may be misleading since it fails to reflect other transportation values such as speed, convenience, and flexibility. Nevertheless, it is often useful in making rapid estimates of total annual transportation cost, given the tonnage and the distance.

Several trends are apparent in Figures 6 through 11. First, for both transportation modes, costs per ton-mile decrease with increasing transportation distance and throughput. Second, the extent of new rail construction or upgrading becomes less important in relation to total costs as the throughput increases. For example, 100-percent new construction adds 50 mills per ton-mile to the cost of hauling 3 million tons per year by rail, while the same percentage of new construction adds only 3 mills per ton-mile when 50 million tons per year are carried.

The relations between slurry and rail costs depend highly upon the throughput and only slightly upon the transportation distance. Table 1 summarizes our findings using the model in this regard. If only upgrading is necessary,

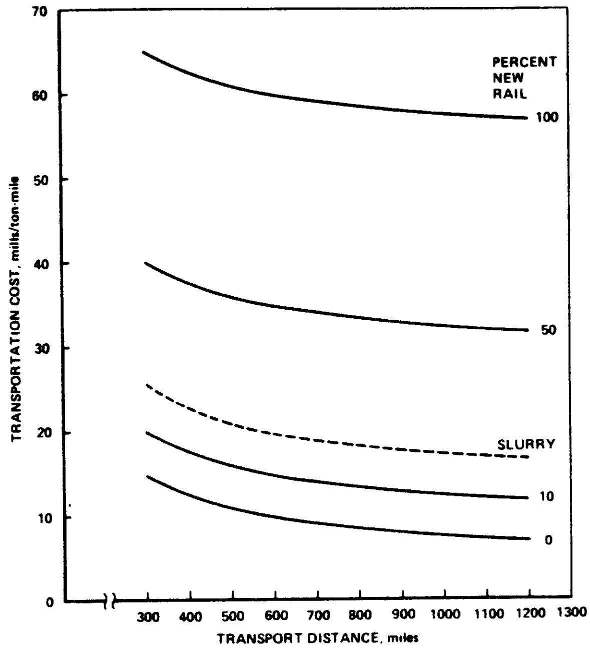

Figure 6: Cost of Transporting 3 Million Tons of Coal by Slurry Pipeline and Railroad with New Construction

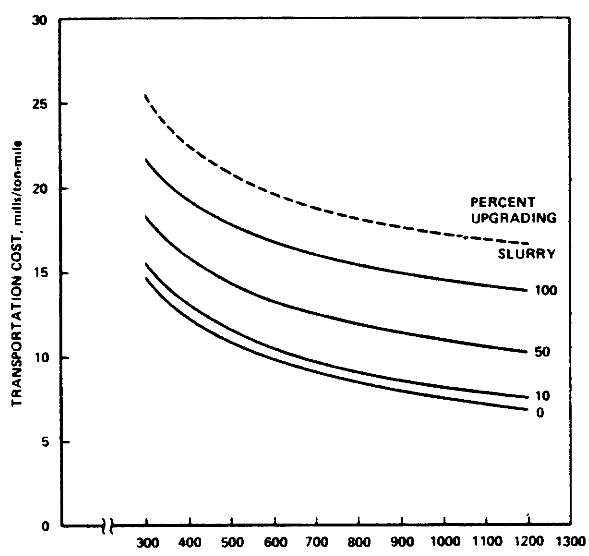

Figure 7: Cost of Transporting 3 Million Tons of Coal by Slurry Pipeline and Railroad with Upgrading

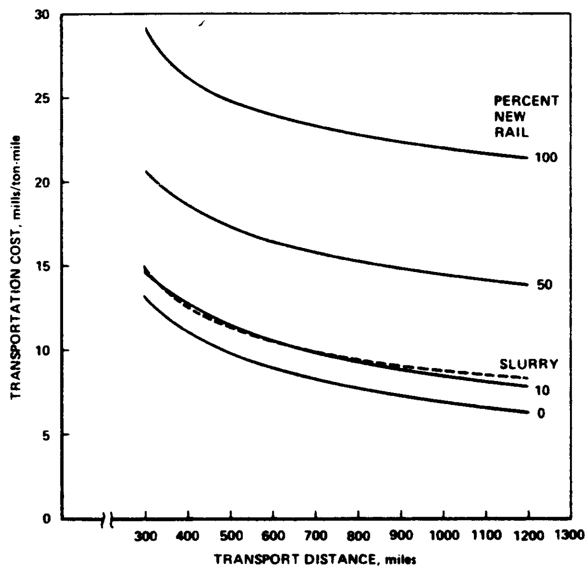

Figure 8: Cost of Transporting 10 Million Tons of Coal by Slurry Pipeline and Railroad with New Construction

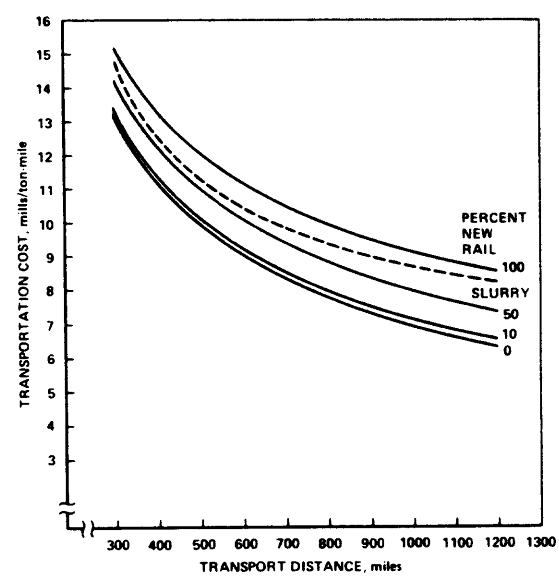

Figure 9: Cost of Transporting 10 Million Tons of Coal by Slurry Pipeline and Railroad with Upgrading

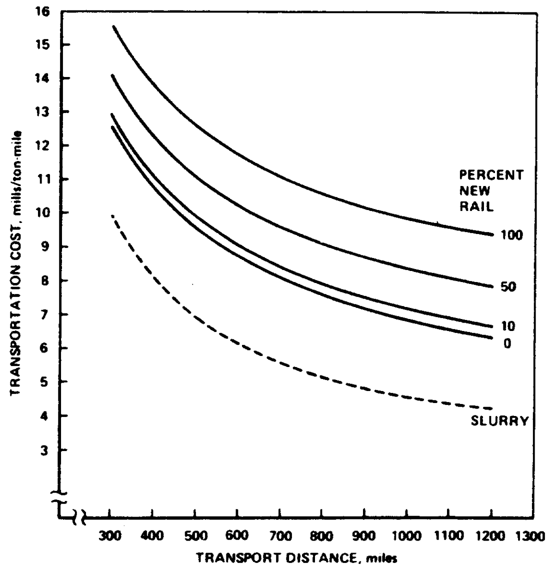

Figure 10: Cost of Transporting 50 Million Tons of Coal by Slurry Pipeline and Railroad with New Construction

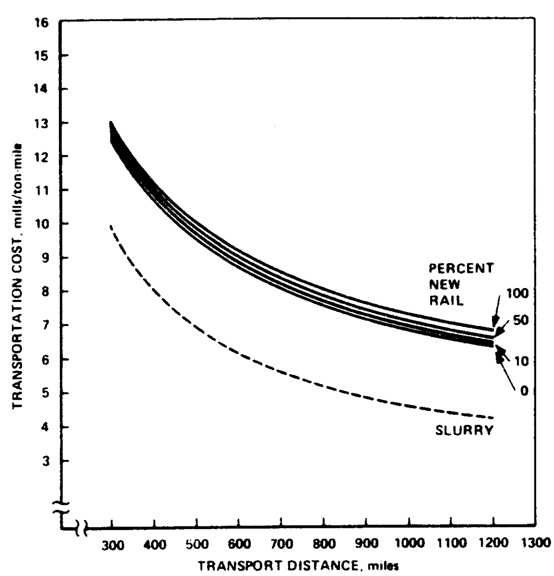

Figure 11: Cost of Transporting 50 Million Tons of Coal by Slurry Pipeline and Railroad with Upgrading

Table 1: Equivalence of Railroad Slurry Costs at Various Tonnages

Tonnage (million tons/year)	A Slurry Pipeline Is Equivalent to a Railroad With:	
	Percent New Rail	Percent Rail Upgrading
3	19	rail always cheaper
10	13	87
50	slurry always cheaper	slurry always cheaper

then the mill per ton-mile cost of a unit train will always be lower than that for a slurry pipeline, if 3 million tons per year are carried. For a throughput of 50 million tons per year, pipelines are always cheaper on a mill per ton-mile basis.

It should be noted that slurry pipelines may be less expensive than trains, despite having higher mill per ton-mile costs, if they traverse a shorter route than the railroad does. Suppose, for example, that 3 million tons per year of coal are to be carried from a coalfield to a powerplant 700 miles (1,130 kilometers) away. The costs of a pipeline and a unit train (with 10 percent new construction) would be, respectively, 19 and 14 mills per ton-mile. However, if a new pipeline could be built over a more direct route of 400 miles (250 kilometers), then its total annual cost ($27 million) would be less than that for the unit train ($29.4 million).

CONCLUSIONS AND RESERVATIONS

Table 1 and Figures 6 through 11 represent reasonable transportation scenarios in the Southwest and may be used as rough guides in transportation decision-making. By including the costs for various percentages of new rail construction or upgrading, we have expanded the suite of scenarios; the choice in future power projects in the Southwest will not be one between an all-new rail system and a slurry pipeline. Our results, however, must be adjusted with actual construction cost data, especially in areas where difficult topography will require bridge and tunnel construction and extensive cuts and fills. In addition, escalating labor and land costs may shift the crossover point between railroad and pipeline costs in the future.

The most important reservation about the results of this analysis, however, is that it reflects only the hard costs of transportation projects and does not take into account the soft costs which, as we have seen earlier in this paper, may be the real constraint upon energy development in the Southwest. A detailed study of potential new rail and pipeline routes in the Southwest is presented in Reference 12; the reader is referred to that study for analyses of specific cases.

ACKNOWLEDGMENTS

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GLOSSARY

Deseret	originally envisioned as the Mormon heavenly kingdom on earth which was to center upon Utah and include Nevada and parts of Southern California, Arizona, New Mexico, northern Mexico, Colorado, and Idaho; presently refers primarily to the State of Utah as a Mormon "homeland"; Zion
load center	an area where energy demand is concentrated, such as a city or an industrial park
slurry pipeline	a pipeline which transmits a suspension of finely divided solids (such as coal or iron ore) in a carrier medium (e.g., water)
throughput	volume or tonnage of material transported
unit train	a train dedicated to carrying a single commodity nonstop between fixed points and according to a strick schedule

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